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TRACTION MODULE

CROSS-REFERENCE TO RELATED APPLICATION

The present application is related to provisional application Serial No. 60/063,326, filed October 27, 1997 entitled Drilling System, to application Serial No. 09/081,961 filed May 20, 1998 entitled Drilling System, and to application Serial No. 09/467,588 filed December 20, 1999 entitled Three Dimensional Steering Assembly, all hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

The present invention relates to anchors or traction modules for thrust loads imparted by well tools, such as a thruster or tractor used in an assembly for performing a downhole operation in a well and more particularly to packer feet on a tractor in a bottom hole assembly, disposed on an umbilical, with a power section for rotating a bit while the tractor moves the bottom hole assembly within the well.

In the course of drilling and completing oil and gas wells, it is sometimes desirable to set an anchor in closed or open hole to serve as a reaction point for various thrust forces imparted by operating tools. Expanding anchors, very much like packers, usually are fluted around the exterior to allow flow to bypass the anchor and up the well annulus. Such externally fluted anchors will sometimes bury themselves in soft formations and completely close off all flow channels causing major well problems.

A thruster or tractor is one well tool which uses anchors as a reaction point. A tractor is part of a bottom hole assembly used on coiled tubing with the bottom hole assembly having a downhole motor providing the power to rotate a bit for drilling the borehole. The bottom hole assembly operates only in the sliding mode since the coiled tubing is not rotated at the surface like that of steel drill pipe which is rotated by a rotary table on the rig. Drilling fluids flow down

the umbilical and through the bottom hole assembly and bit to cool the bit and return the cuttings up the annulus around the bottom hole assembly and umbilical to the surface. The tractor propels the bottom hole assembly down the borehole.

One such self-propelled tractor for propelling the bottom hole assembly in the borehole is manufactured by Western Well Tool and is described in U.S. Patent 6,003,606, hereby incorporated herein by reference. The tractor includes an upper and lower housing with a packerfoot mounted on each end. Each housing has a hydraulic cylinder and ram for moving the propulsion system within the borehole. The tractor operates by the lower packerfoot expanding into engagement with the wall of the borehole with the ram in the lower housing extending in the cylinder to force the bit downhole. Simultaneously, the upper packerfoot contracts and moves to the other end of the upper housing. Once the ram in the lower housing completes its stroke, the upper packerfoot expands, then the hydraulic ram in the upper housing is actuated to propel the bit and motor further downhole as the lower packerfoot contracts and resets at the other end of the lower housing. This cycle is repeated to continuously move the bottom hole assembly within the borehole to drill the well. The tractor can propel the bottom hole assembly in either direction in the borehole.

The packerfoot of the Western Well Tool tractor includes an elastomeric body that inflates when filled with fluid. The elastomeric body can be made of a variety of materials such reinforced graphite or Kevlar. The aft end of the packerfoot attaches to a barrel end which surrounds a cylindrical pipe on the tractor. The barrel end is slidable relative to the cylindrical pipe. The forward end is connected to the barrel end. Seals are located between the barrel end and the packerfoot and between the barrel end and the cylindrical pipe to prevent fluid escape. The packer feet include longitudinal projections or ribs circumferentially spaced around the

external surface of the packerfeet so as to form flutes therebetween to provide a fluid flow area and return flow path between the ribs for the flow of returns through the annulus around the tractor during drilling. The ribs engage the earth bore which has been drilled. These longitudinal projections or ribs are not effective in soft formations because upon expansion of the packerfeet, the ribs penetrate and bury in the soft earth formation causing the flutes to become packed off with earth and closing the return flow path through the annulus for the cuttings. Flow passages must be maintained between the packerfeet and housings to allow the passage of drilling fluids through the tractor to expand the packerfeet and to maintain the drilling. Blockage also causes the packerfeet to be blown off the tractor due to the hydraulic pressure through the annulus.

Another deficiency of prior art packerfeet is that they are made of an elastomeric, stretchable material such that upon expansion, the packerfeet balloon and stretch to engage the borehole wall. Thus when the packerfoot anchors to the borehole wall, all of the axial and torsional loads from the tractor are placed on the stretched material forming the packerfoot. These combined axial tensile loads, expansion stresses and hoop stresses are more than can be handled by a piece of fabric or elastomeric material. The fabric and elastomeric material cannot endure these stresses. Thus it is an objective to prevent the pressure element from taking any of the torsional or axial load from the borehole wall. Another deficiency of the prior art packerfeet is that the amount of radial expansion is small. This is due to the limit that the reinforcing fagric which is embedded in the elastomer can expand to. A means to extend the redial expansion capabilities of packerfeet is highly desirable.

The prior art packerfeet have the further disadvantage in that the ribs do not allow a continuous circumferential contact between the packerfoot and the borehole wall.

The present invention overcomes the deficiencies of the prior art.

SUMMARY OF THE INVENTION

The traction module is preferably mounted on a propulsion tool to anchor the propulsion tool within the wellbore as the propulsion tool applies axial loads and torque to a drill bit. The traction module includes an inner expandable member and an outer member around the inner expandable member such that upon expanding the inner expandable member, the outer cover member expands into engagement with the wall of the borehole. The outer cover member is made of a non-stretchable material and likewise inner expandable member is preferably made from a non-stretchable material. The outer member is decoupled from the inner expandable member such that only the outer member is subjected to the axial and torsional loads of the propulsion system and the inner expandable member may or may not be expanded to its manufactured diameter. The outer cover member preferably includes a plurality of non-collapsible tubes for the passage of fluids through the traction module in its expanded position such that returns from the drilling may flow up the well annulus.

The preferred embodiment of the present invention has many advantages. It provides a fixed fluid flow through area whether in the expanded or contracted position. There is a full 360° borehole wall contact to obtain maximum bearing area, particularly in soft formations. The inner expandable member 108 is completely decoupled from the outer cover member 110 which is in contact with the borehole wall 76 and must withstand the thrust and torsional forces of propulsion system 50. The inner expandable member 108 is manufactured to its full expanded size and does not undergo cyclical stretch and relaxation loading. The inner expandable member 108 is retained mechanically by the reinforced fabric of outer cover member 112 and does not experience hoop stresses upon full actuation pressure.

Other objects and advantages of the present invention will appear from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed description of a preferred embodiment of the invention, reference will now be made to the accompanying drawings wherein:

Figure 1 is a schematic view of an example well with a bottom hole assembly on an umbilical;

Figure 2 is an enlarged perspective view of the bottom hole assembly shown in Figure 1 including the propulsion system with the traction modules of the present invention;

Figure 3 is a cross-sectional schematic view of the propulsion system shown in Figure 2;

Figure 4 is a cross-sectional view taken at plane 4-4 in Figure 3 showing one of the traction modules;

Figure 5 is a side elevation view of a traction module of the propulsion system in the contracted position;

Figure 6 is an end view of the traction module of Figure 5;

Figure 7 is a side elevation view of a traction module of the propulsion system in the expanded position; and

Figure 8 is an end view of the traction module of Figure 7.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention relates to methods and apparatus for anchoring a well tool in a well. The present invention is susceptible to embodiments of different forms. There are shown in the drawings, and herein will be described in detail, specific embodiments of the present invention with the understanding that the present disclosure is to be considered an

exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein.

In particular, various embodiments of the present invention provide a number of different constructions and methods of operation of the traction module, each of which may be used to anchor a well tool in a borehole, casing, or pipe for a well including a new borehole, an extended reach borehole, extending an existing borehole, a sidetracked borehole, a deviated borehole, enlarging a existing borehole, reaming an existing borehole, and other types of boreholes for drilling and completing a production zone. The embodiments of the present invention also provide a plurality of methods for using the traction module of the present invention. It is to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce desired results. In particular the present system may be used in practically any type of downhole tractor or thruster. Reference to "up", "upstream", "down", or "downstream" are made for purposes of ease of description with "up" or "upstream" meaning away from the bit and "down" or "downstream" meaning toward the bit.

Referring initially to Figure 1, there is shown a coiled tubing system 10 as an exemplary operating environment for the present invention. Coiled tubing operation system 10 includes a power supply 12, a surface processor 14, and a coiled tubing spool 16. An injector head unit 18 feeds and directs coiled tubing 20 from the spool 16 into the well 22. The coiled tubing 20 is preferably composite coiled tubing. A bottom hole assembly 30 is shown attached to the lower end of composite coiled tubing 20 and extending into a deviated or horizontal borehole 24. It should be appreciated that this embodiment is described for explanatory purposes and that the

present invention is not limited to the particular borehole disclosed, it being appreciated that the present invention may be used for various well plans.

As shown in Figure 2, bottom hole assembly 30 typically includes a bit 32, a steering assembly 34, a power section 36, a resistivity tool 38, and an orientation package 40. Further, the downhole assembly 30 includes a propulsion system 50 having a lower tractor back pressure control module 42, a lower tension/compression sub 44, pressure measurement sub 46, an upper tractor back pressure control module 48, an upper tension/compression sub 52, a supervisory sub 54, and a flapper ball drop 56. The bottom hole assembly 30 is connected to a work string 58 extending to the surface 60 of the well 22.

It should be appreciated that other tools may be included in the bottom hole assembly 30. The tools making up the bottom hole assembly 30 will vary depending on the well operation to be performed. It should be appreciated that the present invention is not limited to a particular propulsion system 50 and other alternative assemblies may also be used. Further details on the individual components of the bottom hole assembly 1Q and their operation may be found in U. S. provisional application Serial No. 60/063,326, filed October 27, 1997 entitled "Drilling System", U. S. patent application Serial No. 09/081,961 filed May 20, 1998 entitled "Drilling System", and U.S patent application Serial No. 09/467,588 filed December 20, 1999 entitled Three Dimensional Steering Assembly, all hereby incorporated herein by reference.

Referring now to Figures 3 and 4, there is shown a schematic of the propulsion system 50 which includes a housing 62 having a central tubular member 64 forming a flow bore 66 therethrough for the passage of drilling fluids flowing down through the composite umbilical 20 from the surface 60. For self-propulsion, propulsion system 50 includes a downstream packer-

like traction module 70 and an upstream packer-like traction module 72. It should be appreciated that the propulsion system 50 may include more than two traction modules.

As best shown in Figure 4, there is shown a cross-section of traction module 70. Since traction modules 70, 72 are similar in construction, a description of one traction module approximates the description of the other. Traction module 70 includes steel feet 74 around its outer circumference which may be expanded and contracted into engagement with the wall of borehole 76. A plurality of longitudinal fluid flow passages 78 are provided around the inner circumference of the steel bands forming feet 74 to allow drilling fluid to flow upstream through annulus 80 when traction module 70 is expanded into engagement with the wall of borehole 76. Traction modules 70, 72 may have independently inflatable, individual chambers for expanding modules 70, 72 eccentrically with respect to the housing 62.

Housing 62 includes a downstream housing section 82 having a tubular cylinder 84 in which is disposed a hydraulic ram 86 on which is mounted downstream traction module 70. Hydraulic ports 88, 90 are disposed at the opposite sides of ram 86 in tubular cylinder 84 for applying hydraulic pressure to ram 86. Hydraulic ports 92, 94 are disposed at opposite sides of ram 96 in tubular cylinder 100 for applying hydraulic pressure to ram 96. Hydraulic ports, 73 and 75, are disposed in tubular member 62 to expand and contract the traction modules 70 and 72 in and out of engagement with the wall of borehole 76. It should also be appreciated that propulsion system 50 includes a series of valves (not shown) using fluid pressure for the actuation of traction modules 70, 72 and rams 86, 96 mounted on traction modules 70, 72, respectively.

The cycle of propulsion system 50 includes expanding downstream traction module 70 by applying hydraulic pressure through port 73 into engagement with the interior of borehole 76

with the upstream traction module 72 in the contracted and non-engaged position. Hydraulic pressure is applied through hydraulic ports 88 applying pressure to ram 86. As pressure is applied against ram 86 which is attached to housing 62, housing 62 moves down hole driving bit 32 forwardly downhole. Hydraulic fluid is simultaneously applied through hydraulic port 94 causing contracted upstream traction module 72 to move backward on upstream ram 98. Upstream traction module 72 moves with housing 62 moving downhole. Once the downstream traction module 70 reaches the upstream end of tubular cylinder 84, it has completed its forward stroke and is contracted. Simultaneously, upstream traction module 72 has now completed its travel to the downstream end of tubular cylinder 99 and it is in its reset position to start its downward stroke of bit 32. Traction module 72 is then expanded into engagement with borehole 76. As hydraulic pressure is applied through hydraulic port 92 and against upstream ram 96, propulsion system 50 strokes downwardly against bit 32. Simultaneously, downstream traction module 70 is contracted and reset by applying hydraulic pressure through upstream port 90. The cycle is then repeated allowing the propulsion system 50 to move continuously downstream in one fluid motion and provide a downward pressure on drill bit 32.

It should be appreciated that the hydraulic actuation may be reversed whereby propulsion system 50 may be moved upstream in borehole 76. In other words, propulsion system 50 can walk either forward, downstream, or backward, upstream in borehole 76.

Western Well Tool, Inc. manufactures a tractor having expandable and contractible upstream and downstream packerfeet mounted on a hydraulic ram and cylinder for self-propelling drilling bits. The Western Well Tool tractor is described in a European patent application PCT/US96/13573 filed August 22, 1996 and published March 6, 1997, publication No. WO 97/08418, and U.S. Patent 6,003,606, both hereby incorporated herein by reference.

Other propulsion systems may also be adapted for use with the traction modules of the present invention. Other types of tractors include an inchworm by Camco International, Inc., U.S. Patent 5,394,951, incorporated herein by reference and by Honda, U. S. Patent 5,662,020, incorporated herein by reference. Also robotic tractors are produced by Martin Marietta Energy Systems, Inc. and are disclosed in U.S. Patents 5,497,707 and 5,601,025, each incorporated herein by reference. Another company manufactures a tractor which it calls a "Helix". See also "Inchworm Mobility – Stable, Reliable and Inexpensive," by Alexander Ferworn and Deborah Stacey ; "Oil Well Tractor" by CSIRO-UTS of Australia; "Well Tractor for Use in Deviated and Horizontal Wells" by Fredrik Schussler; "Extending the Reach of Coiled Tubing Drilling (Thrusters, Equalizers, and Tractors)" by L.J. Leising, E.C. Onyia, S.C. Townsend, P.R. Paslay and D.A. Stein, SPE Paper 37656, 1997, all incorporated herein by reference. See also "Well Tractors for Highly Deviated and Horizontal Wells", SPE Paper 28871 presented at the 1994 SPE European Petroleum Conference, London Oct. 25-27, 1994, incorporated herein by reference.

During drilling, drilling fluids flow down the flowbore 66 of composite umbilical 20, through propulsion system 50 and flowbore 66, through power section 36, through the bit 32 and back up the annulus 80 to the surface 60. Where the power section 36 is a downhole positive displacement motor, turbine, or other hydraulic motor, the drilling fluids rotate the rotor within the stator causing the output shaft attached to the bit 32 to operatively rotate bit 32. The propulsion system 50 propels the bit 32 into the formation for drilling the new borehole 76. The only rotating portion of the bottom hole assembly 30 is the power section and bit 32. The umbilical 20 and the remainder of the bottom hole assembly 30 do not rotate within the borehole 76.

It should further be appreciated that the traction modules may be used on tractors or thrusters on a bottom hole assembly to perform other operations in a well. Such well tools include a well intervention tool, a well stimulation tool, a logging tool, a density engineering tool, a perforating tool, or a mill.

Referring now to Figures 5-8, there is shown a preferred embodiment of the traction module 100 which may be used as the traction modules 70, 72 on propulsion system 50. Traction module 100 is shown in the contracted position in Figures 5 and 6 and in the expanded and engaged position in Figures 7 and 8. As best shown in Figures 7 and 8, traction module 100 is shown in gripping engagement at 102 with borehole wall 76. It should be appreciated that traction module 100 is not shown to scale in Figures 5-8 and has been enlarged, as compared to borehole 76 and housing 62 of propulsion system 50, for clarity. It should also be appreciated that housing 62 of propulsion system 50 is only shown schematically again for clarity. Further, hydraulic ports 104 are shown through housing 62 for communicating the drilling fluid pressure in flowbore 66 with a chamber 106 around housing 62. However, it should be appreciated that ports 104 are shown schematically and in fact represent a valving mechanism in propulsion system 50 such as that disclosed in U.S. Patent 6,003,606, hereby incorporated herein by reference.

Traction module 100 includes an inner expandable member 108, a cover member 110, and a plurality of flow tubes 112. Flow tubes 112 have a kidney shaped cross-section formed by an inner arcuate side 114 and an outer arcuate side 116 with inner arcuate side 114 forming a larger arc and outer arcuate side 116 having a smaller arc whereby inner arcuate side 114 better conforms to the outer surface of housing 62 and outer arcuate surface 116 better conforms with the inside diameter of borehole wall 76. Flow tubes 112 are preferably thin walled metal tubes

made of steel and may be produced from a round tube which is placed in a die and shaped to conform to the preferred cross-section. As best shown in Figures 5 and 7, flow tubes 112 preferably have tapered ends 118.

Cover member 110 is preferably made of a fabric material which does not stretch. One preferred material is reinforced Neoprene or a Kevlar fabric with Neoprene coating. A material similar to that used for the packerfeet described in U.S. Patent 6,003,606 may also be used. The cover member 110 is bonded around each of the flow tubes 112 so as to over wrap each of the flow members 112 leaving the ends 118 open for the passage of fluids through each of the flow paths 120 in flow tubes 112. As best shown in Figure 8, cover member 110 is sized to have a diameter slightly greater than the diameter of borehole 76 being drilled. Some over size is required so that traction module 100 will engage the earth bore wall 76 where wash outs have occurred thus causing borehole 76 to be enlarged and uneven. If a slightly reduced diameter borehole is encountered, spaces 122 may occur between cover member 110 and borehole 76 where cover member 20 is not fully expanded. It is preferred that cover member 110 fully and completely engage the borehole wall around its circumference to maximize the gripping engagement between traction module 100 and borehole 76. As best shown in Figure 6, the cover member 110 tends to form folds 124 between adjacent flow tubes 112 in the contracted position.

The tapered ends 118 conform to the cover member 110 in the expanded position as shown in Figure 7. The fabric encompasses flow tubes 112 causing the tubes 112 to be embedded in the fabric material. There may be multiple layers of fabric material around the flow tubes 112. It is preferred that fabric material 110 be molded to flow tubes 110 and around the openings 118 of flow tubes 110.

The inner expandable member 108 is preferably a balloon or bladder which is made of a material that does not stretch. Inner expandable member 108 may be made of a reinforced or non-reinforced Nitrile rubber and also may be made of a reinforced fabric that does not stretch. The expandable member 108 thus may only expand to its manufactured outer diameter. It should be appreciated that inner expandable member 108 is a separate and independent member from that of cover member 110 whereby the two members are decoupled. The inner expandable member 108 serves only as a sealing element for chamber 106. As shown in Figure 8, inner expandable member 108 expands upon the pressurization of chamber 106 to force cover member 110 into its expanded state. As shown in Figure 6, in the contracted position, inner expandable member 108 folds together into a plurality of folds 126.

Referring now to Figures 5 and 7, traction member 100 is mounted on housing 62 of propulsion system 50. At one end 128, the adjacent ends of expandable member 108 and cover member 110 are fixed to housing 62 such as by a metal ring. Seals 130 are provided between expandable member 108, cover member 110, and housing 62. The other end 132 of traction module 100 is mounted on a floating or sliding ring 134 disposed around housing 62. The ends of expandable member 108 and cover member 110 are sealed with ring 134 by seals 136. Floating ring 134 allows end 132 to float or slide along housing 62 as traction module 100 expands and contracts. Seals 130, 136 may be O-ring seals.

In operation, inner expandable member 108 is inflated using the valving assembly 104 in housing 62 of propulsion system 50 by the drilling fluids flowing through flowbore 66. The flowbore pressure increases the fluid pressure within chamber 106 formed within expandable member 108. This increase in fluid pressure causes expandable member 108 to expand thus expanding cover member 110. Cover member 110 expands towards its full diameter and into

gripping engagement with the borehole wall 76. The expansion of cover member 110 into engagement with borehole wall 76 provides a full, 360° bearing surface therebetween causing traction module 100 to fully frictionally engage borehole wall 76. It should be appreciated that while borehole wall 76 is shown to be circular in Figures 6 and 8, in fact, borehole wall 76 is uneven and may include wash out areas forming an irregular cross-section. Cover member 110 expands to its diameter in conformance with the shape of earth bore wall 76. As shown in Figure 8, cover member 110 in its expanded position may or may not fully engage the earth bore wall 76 at all locations leaving certain inner spatial areas 122 such as between adjacent flow tubes 112. Spatial areas 122 will be at a minimum since the fabric of the cover member 110 will be tight around its outer cicumference.

The circumference and length of cover member 110 is fixed. Thus, as it expands, folds 124 are removed. However, because cover member 110 is a fabric made of Kevlar, or other heavy fabric reinforced rubber, cover member 110 does not stretch. When cover member 110 reaches its maximum diameter, no further expansion occurs. Upon cover member 112 reaching its maximum diameter, the interior of cover member 110 then restrains the further expansion of inner expandable member 108. Thus, expandable member 108 is not expanded fully due to flowbore pressure through flowbore 66 and is not subjected to any differential pressure between flowbore 66 and annulus 138 because expandable member 108 only occupies that area between housing 66 and the inside of cover member 110. Outer cover member 110 is subjected to the inner flowbore pressure and the frictional engagement with borehole wall 76 and thus is subjected to the tension, compression, and torque imparted by the operation of compulsion system 50. Therefore, there is no cyclic stretch and relaxation of either expandable member 108 or cover member 110. Inner expandable member 108 must only hold and contain fluid pressure.

Cover member 110 may only be expanded to its pre-manufactured maximum diameter and does not stretch so as to engage the borehole wall as in the prior art. The prior art packer feet must not only stretch to engage the borehole but the stretched material must also absorb and withstand the imparted high loads of the propulsion tool while in the stretched condition.

Since the cover member 110 need not stretch to engage the wellbore 76, there is no cyclic loading of cover member 110 and the expansion forces on inner expandable member 108 are decoupled from the frictional engagement of the cover member 110 with borehole wall 76. The heavily reinforced, non-stretchable fabric of the cover member 110 takes all of the axial loads and torque from propulsion tool 50. Since cover member 112 is not an expandable and stretchable material, it is not stressed while at the same time taking the loads imparted by the propulsion tool 50. Such stresses are avoided because inner expandable member 108 is decoupled and independent of outer cover member 110.

As shown in Figures 5 and 7, flow tubes 112 remain open whether in the contracted or expanded position. Therefore, flow tubes 112 maintain a constant cross-section and thus a minimum flow area around propulsion system 50 and through the annulus 138 while the traction module 100 is in engagement with the wellbore 76. Thus, flow tubes 112 serve as part of the return flow path for the fluids flowing through annulus 138. Since flow tubes 112 are metal, they do not expand or contract with the expansion and contraction of traction module 100. Thus, the flow paths 120 through traction module 100 are set whether in engagement or non-engagement with wellbore 76.

The floating end 132 allows traction module 100 to elevate outwardly to achieve its maximum diameter. Thus, floating end 132 allows traction module 100 to move from its

contracted position with a minimum diameter 140 shown in Figure 5 to its expanded position with a maximum diameter of 142.

The preferred embodiment of the present invention has many advantages. It provides a fixed fluid flow through area whether in the expanded or contracted position. There is a full 360° borehole wall contact to obtain maximum bearing area, particularly in soft formations. The inner expandable member 108 is completely decoupled from the outer cover member 110 which is in contact with the borehole wall 76 and must withstand the thrust and torsional forces of propulsion system 50. The inner expandable member 108 is manufactured to its full expanded size and does not undergo cyclical stretch and relaxation loading. The inner expandable member 108 is retained mechanically by the reinforced fabric of outer cover member 112 and does not experience hoop stresses upon full actuation pressure.

While a preferred embodiment of the invention has been shown and described, modifications thereof can be made by one skilled in the art without departing from the spirit of the invention.